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**Hiramatu et al.**

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(54) **ELECTRONIC BALLAST AND LUMINAIRE WITH THE SAME**

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None  
See application file for complete search history.

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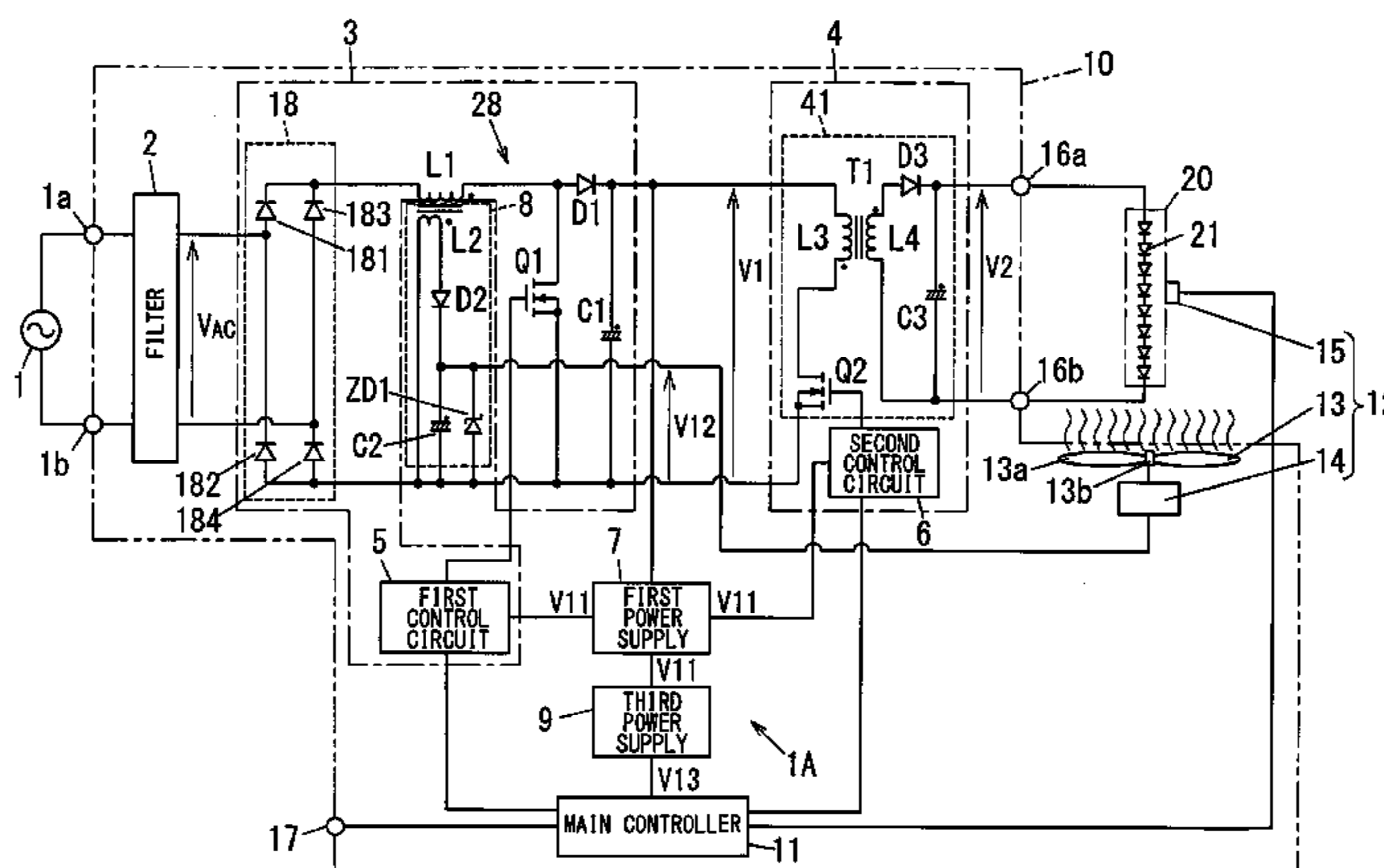
(57) **ABSTRACT**

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**F21V 29/00** (2015.01)  
**F21S 8/02** (2006.01)  
**F21V 23/02** (2006.01)  
**F21V 23/04** (2006.01)  
**F21Y 101/02** (2006.01)  
**F21V 29/70** (2015.01)

An electronic ballast includes an AC-DC converter, a DC-DC converter, a cooling device and a power supply. The cooling device is configured to cool the light source. The power supply includes a first power supply configured to generate a first operating voltage from a first voltage obtained from a chopper circuit included in the AC-DC converter to supply the first operating voltage to at least one of the AC-DC converter and the DC-DC converter. The power supply further includes a second power supply configured to generate a second operating voltage from a second voltage obtained from the chopper circuit to supply the second operating voltage to at least the cooling device of the AC-DC converter, the DC-DC converter and the cooling device.

(52) **U.S. Cl.**  
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**4 Claims, 6 Drawing Sheets**



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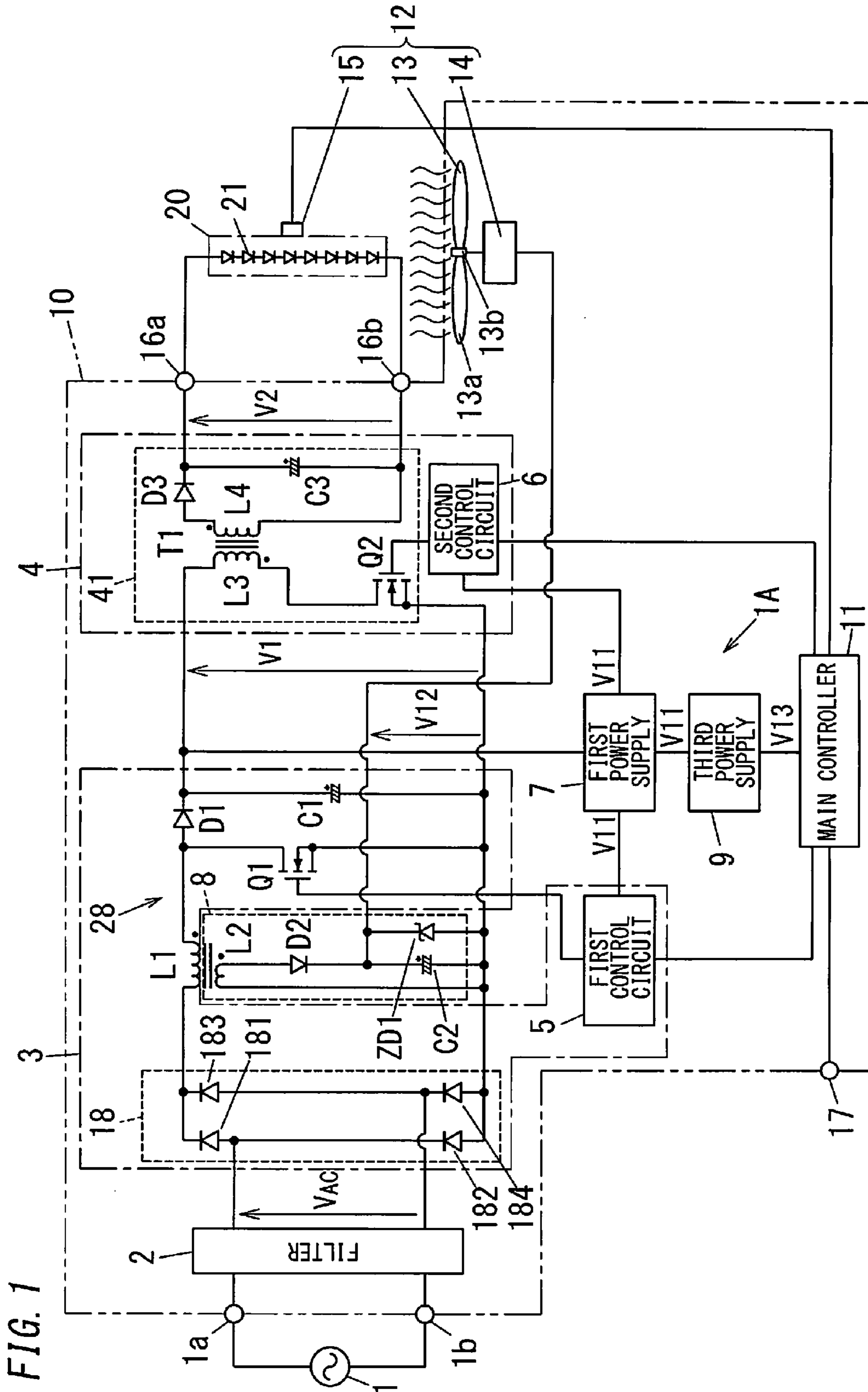


FIG. 1

FIG. 2A

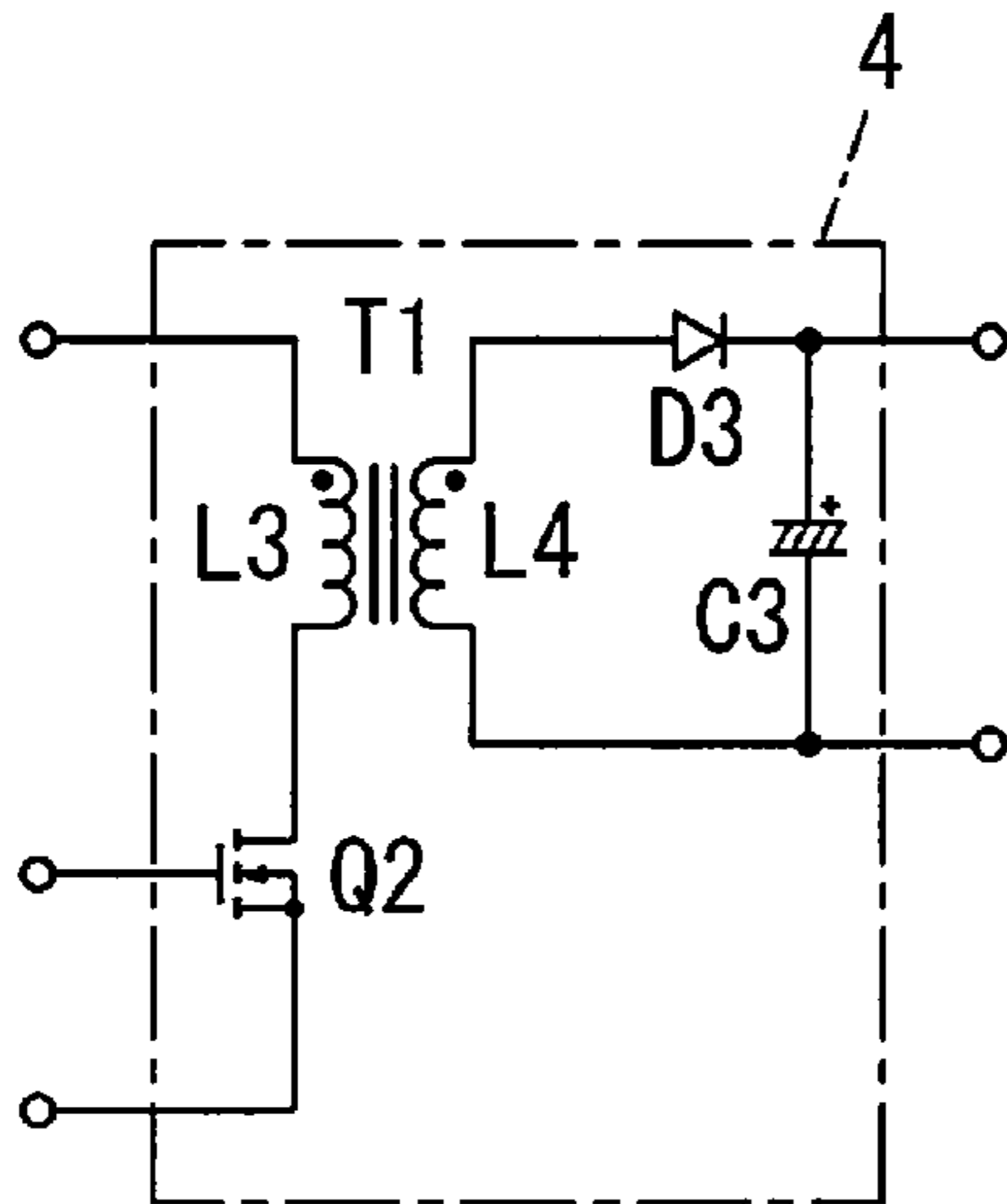


FIG. 2B

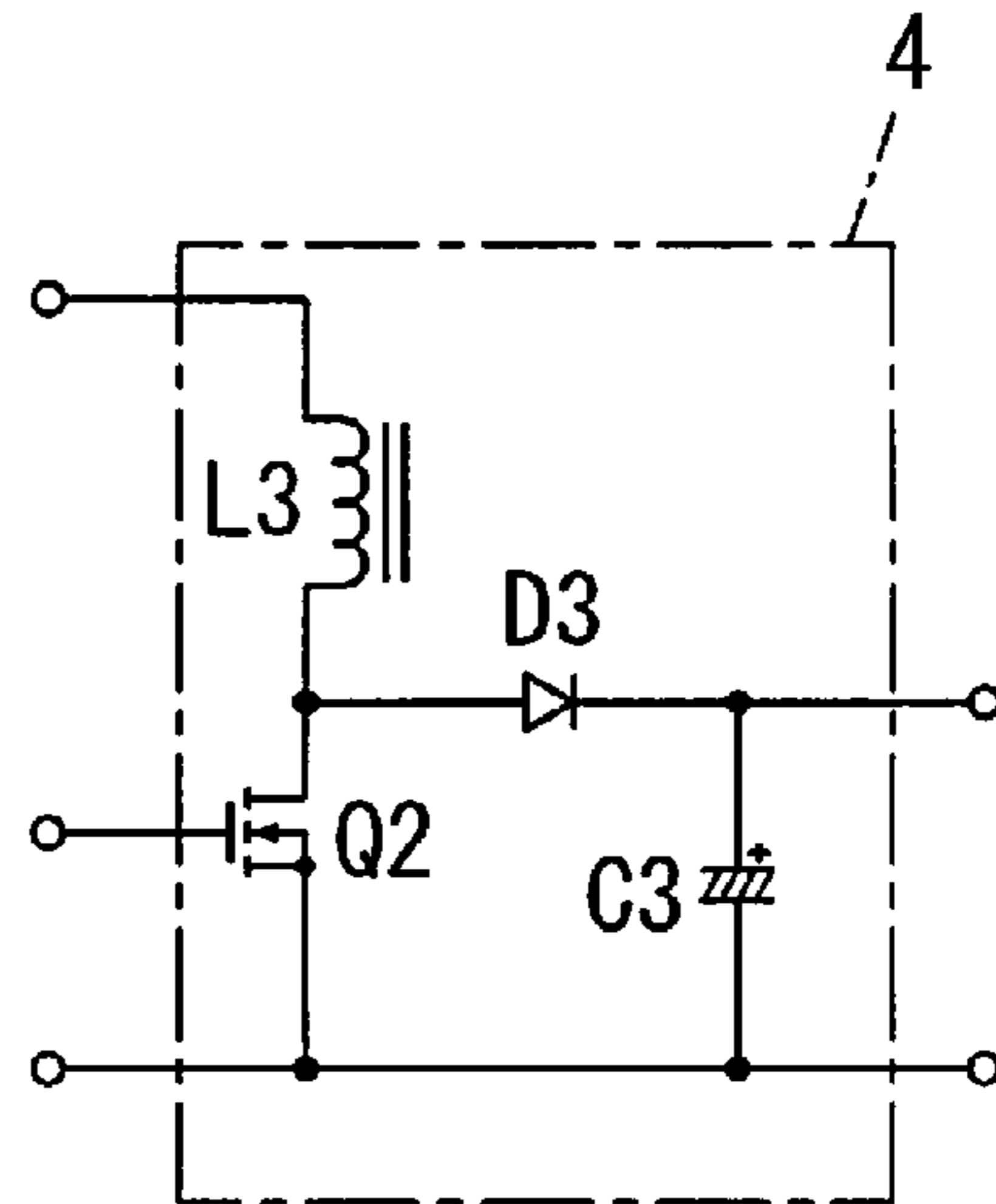


FIG. 2C

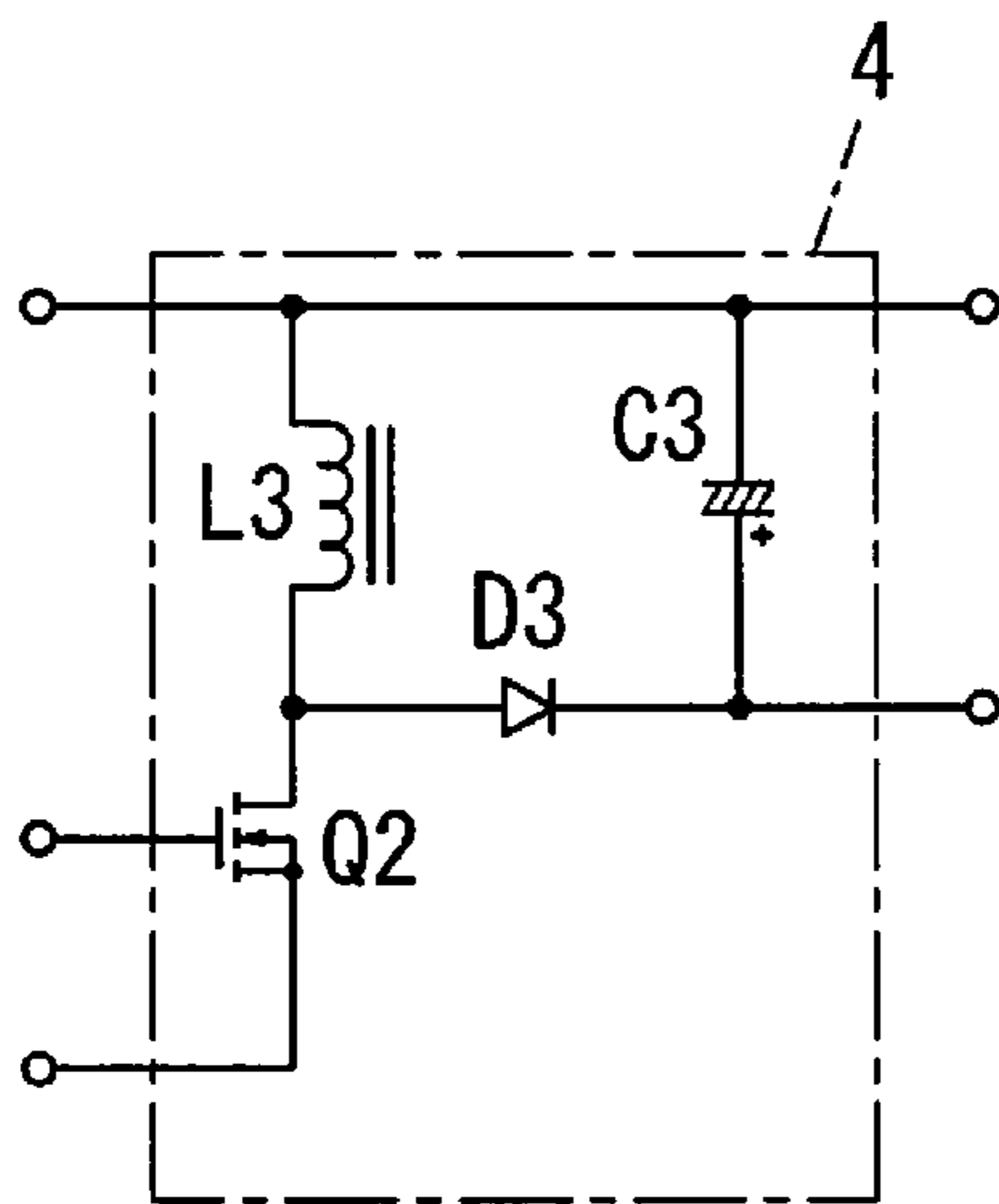


FIG. 2D

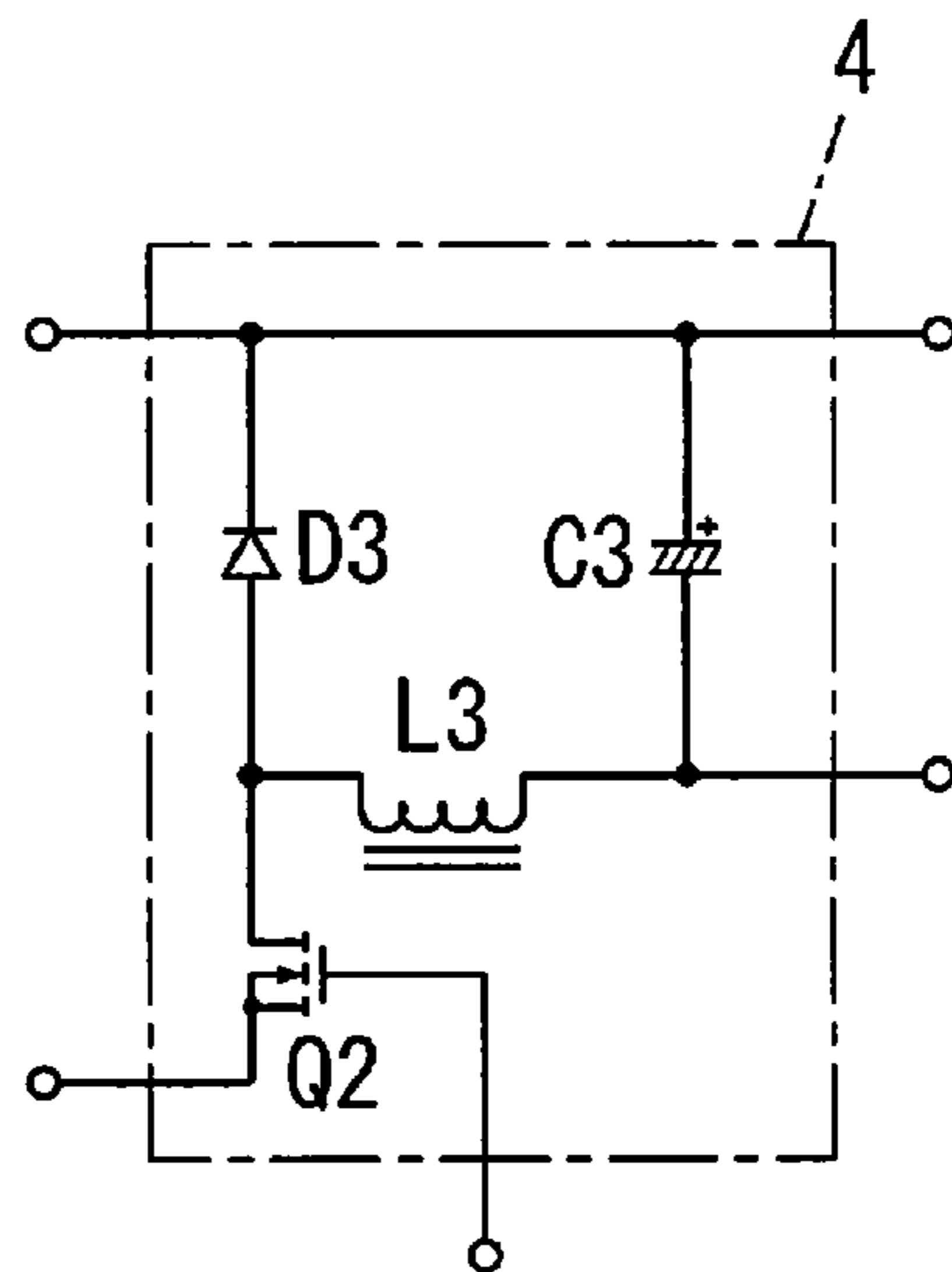


FIG. 3

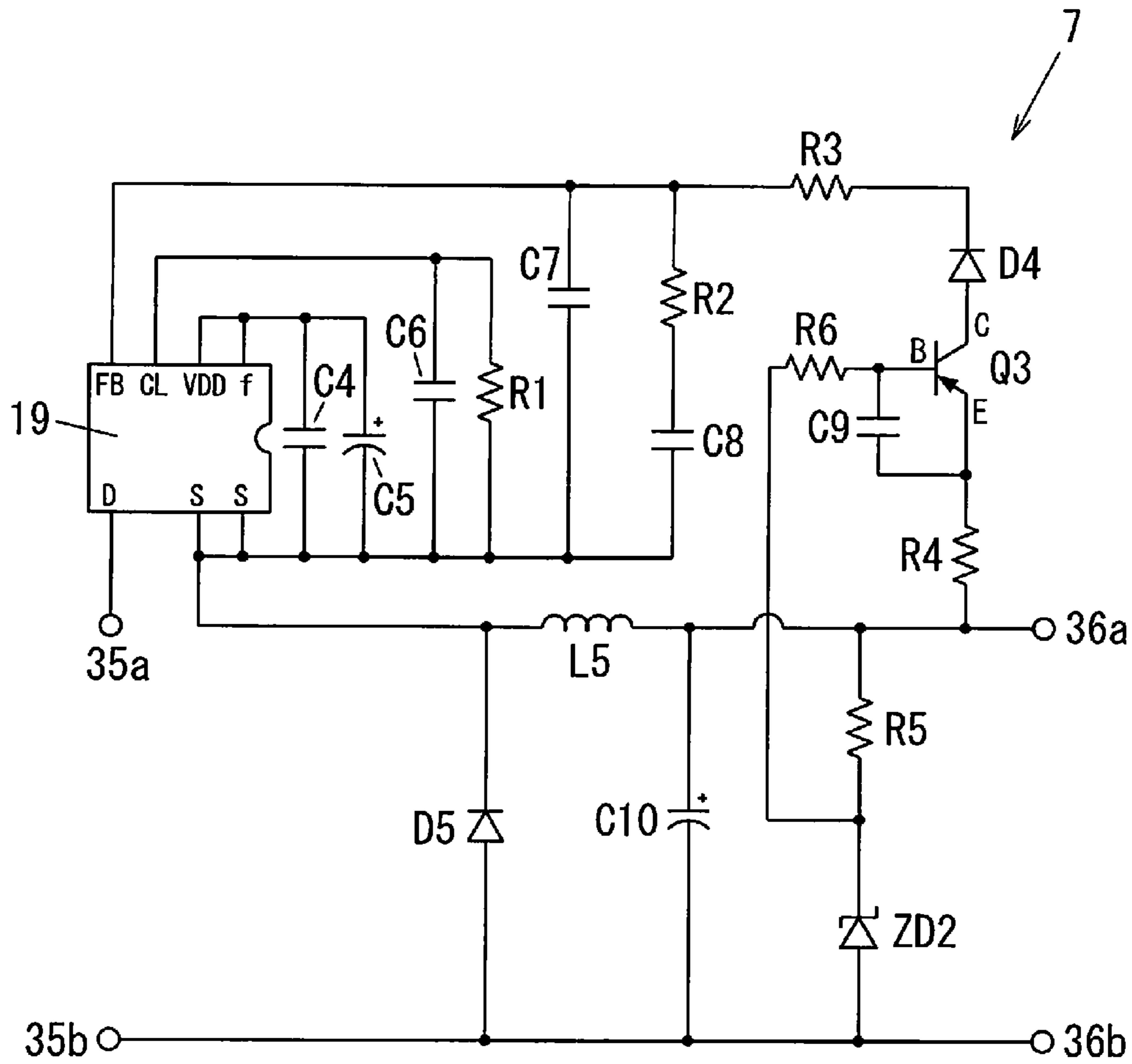
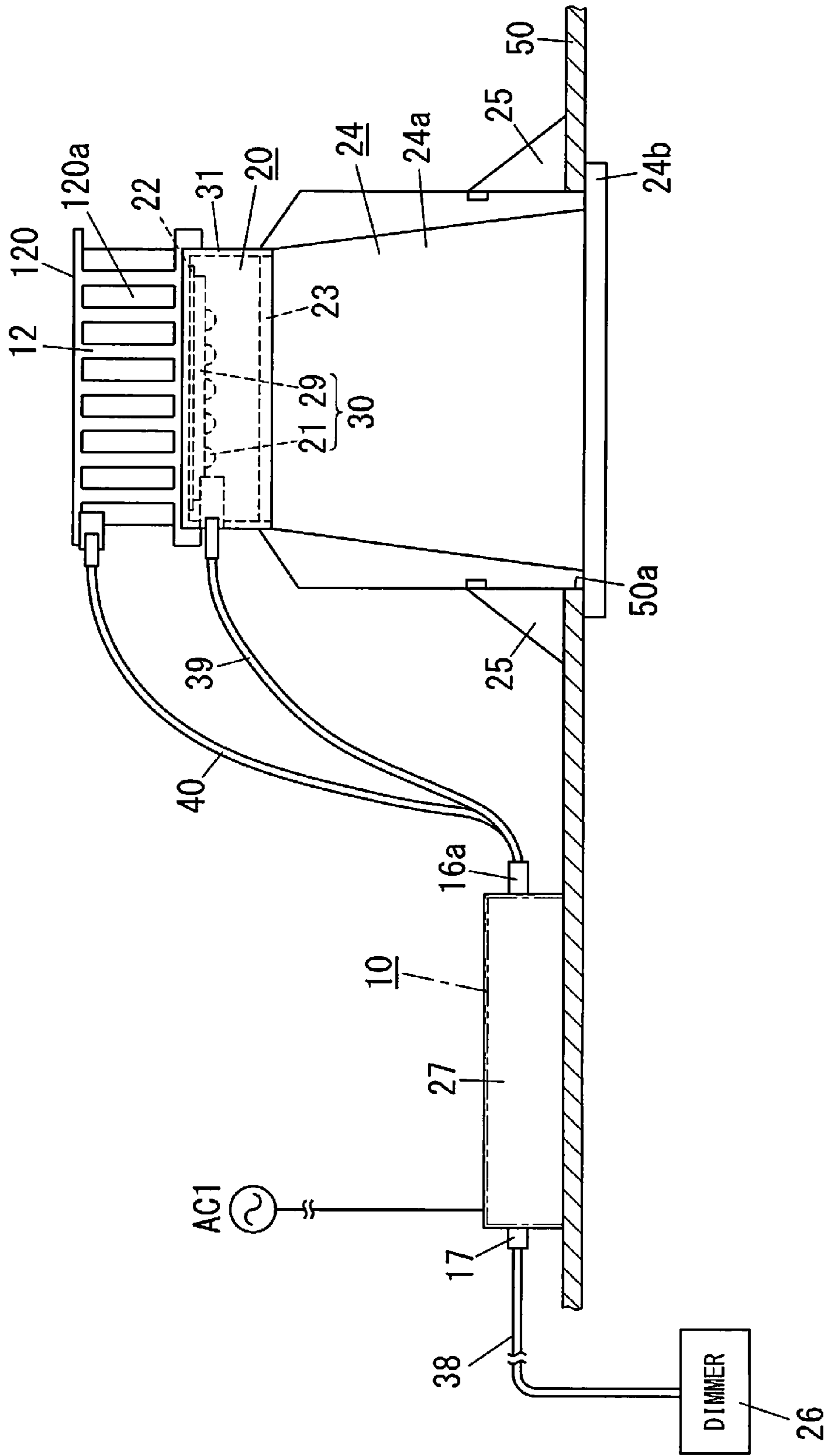


FIG. 4





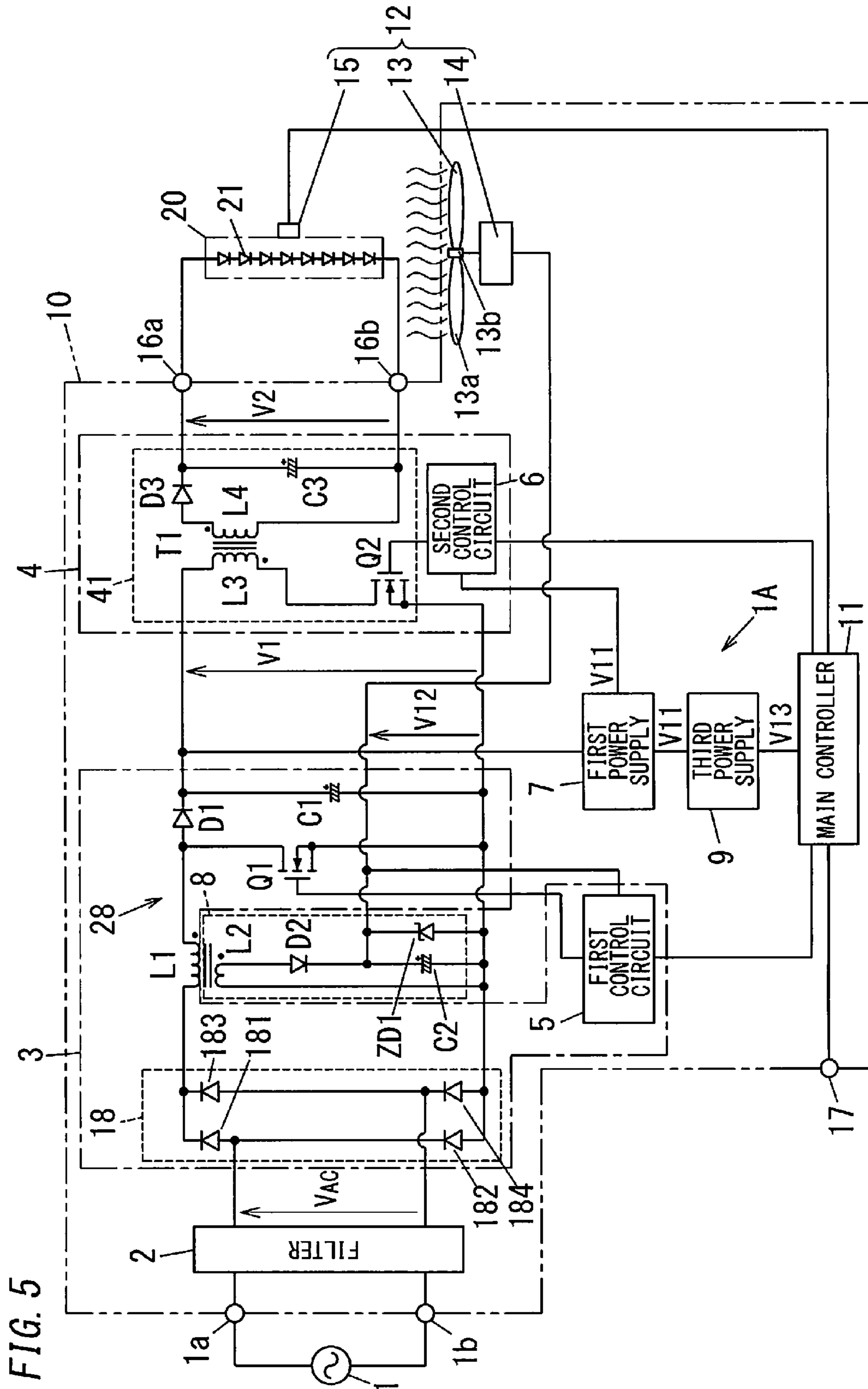
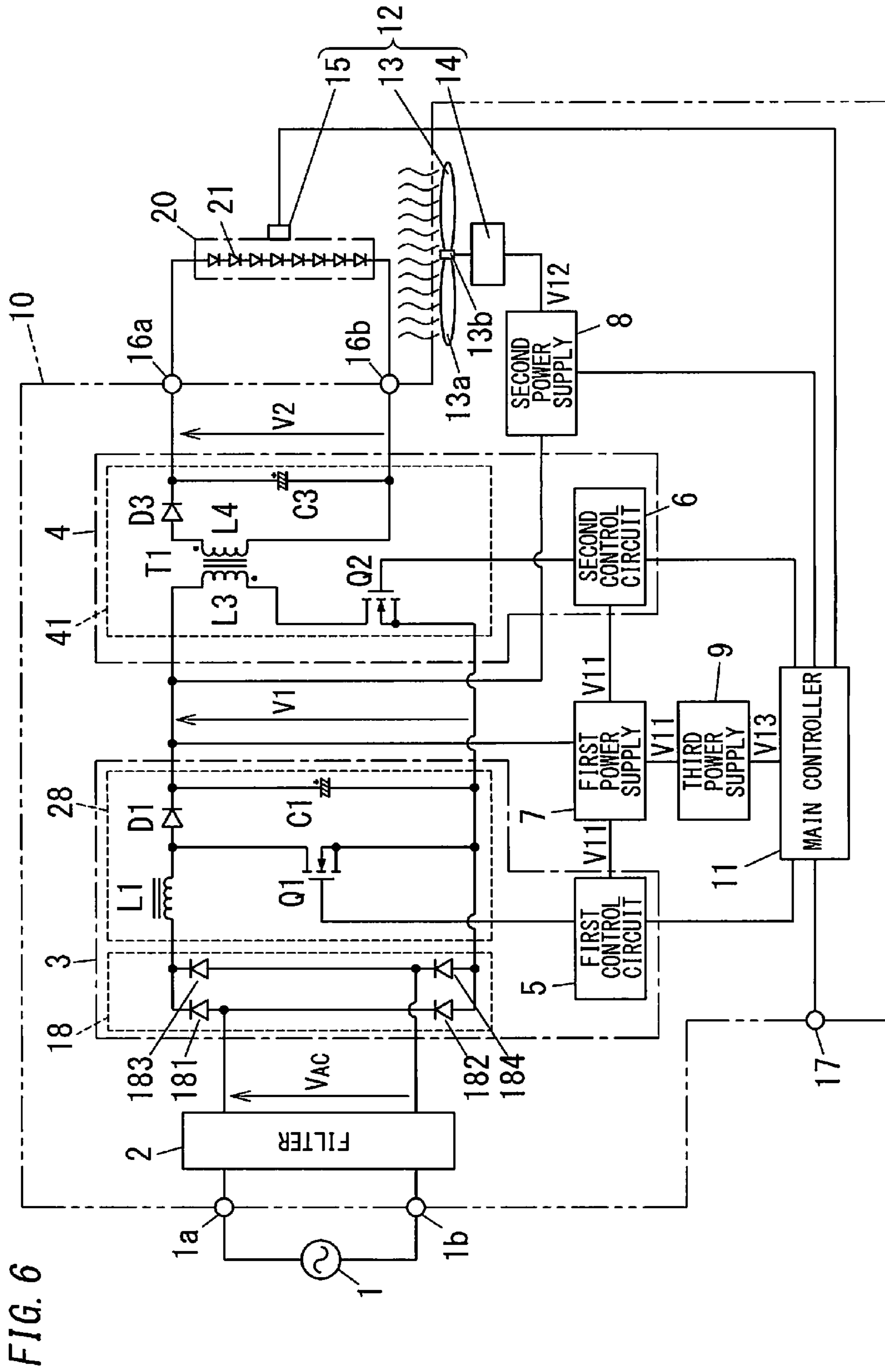


FIG. 5





## ELECTRONIC BALLAST AND LUMINAIRE WITH THE SAME

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit and priority of Japanese Patent Application No. 2013-164306, filed on Aug. 7, 2013, entitled "ELECTRONIC BALLAST AND LUMINAIRE WITH THE SAME", and Japanese Patent Application No. 2013-164307, filed on Aug. 7, 2013, entitled "ELECTRONIC BALLAST AND LUMINAIRE WITH THE SAME", the entire contents of which are incorporated herein by reference.

### TECHNICAL FIELD

This disclosure relates generally to electronic ballasts and luminaires and, more particularly, to an electronic ballast (a lighting device) for a light source that includes at least a solid-state light-emitting device, and a luminaire with the same.

### BACKGROUND ART

Light emitting modules with LEDs (light-emitting diodes) have been provided as a light source for a luminaire in recent years.

In general, a light emitting module has a tendency to decrease an output of the light emitting module and shorten useful life of the light emitting module as a result of rise in LEDs' temperature. It is therefore important to prevent LEDs' temperature from rising in order to prolong the useful life of the light emitting module in a luminaire with the light emitting module. A luminaire with a light emitting module including LEDs to be driven with high-power requires further preventing LEDs' temperature from rising.

For example, JP Pub. No. 2011-150936 (hereinafter referred to as "Document 1") discloses an LED lighting device having a cooling means such as a fan, and a lighting device.

The LED lighting device described in Document 1 includes LED series circuits and a cooling means driver. The series circuits are connected between output terminals of a DC power supply. The cooling means driver is connected between both ends of a part of the series circuits, including at least one or more LEDs, and configured to cool heat generated by the LEDs. The LED lighting device can effectively prevent its own LEDs' temperature from rising.

A stable voltage can be secured without specially providing the cooling means driver with a power supply. In a case where a fan is employed as a cooling means, the cooling means driver is to drive a fan motor. In this case, the cooling means driver requires a DC voltage of about 6V as DC power for driving the fan motor, and is accordingly supplied with a sum of forward voltages of two LEDs in the series circuit, namely a stable DC voltage of about 6V.

In the LED lighting device of Document D1, there is however difficulty in further preventing LEDs' temperature from rising because only a DC voltage of about 6V is supplied to the fan motor of the cooling means driver.

### SUMMARY OF THE INVENTION

It is an object of the present invention to provide an electronic ballast (an LED ballast) capable of supplying a stable

voltage to a cooling device and further preventing light source's temperature from rising, and a luminaire with the same.

According to an aspect of the present invention, an electronic ballast (10) comprises an AC-DC converter (3), a DC-DC converter (4), a cooling device (12) and a power supply (1A). The AC-DC converter (3) comprises a chopper circuit (28) configured to convert an AC voltage ( $V_{AC}$ ) from a commercial power supply (1) into a first DC voltage (V1). The DC-DC converter (4) comprises a DC-DC conversion circuit (41) configured to convert the first DC voltage (V1) into a second DC voltage (V2) to supply the second DC voltage (V2) to a light source (20) including at least a solid-state light-emitting device (21). The cooling device (12) is configured to cool the light source (20). The power supply (1A) comprises a first power supply (7) and a second power supply (8). The first power supply (7) is configured to generate a first operating voltage (V11) from a first voltage obtained from the chopper circuit (28) to supply the first operating voltage (V11) to at least one of the AC-DC converter (3) and the DC-DC converter (4). The second power supply (8) is configured to generate a second operating voltage (V12) from a second voltage obtained from the chopper circuit (28) to supply the second operating voltage (V12) to at least the cooling device (12) of the AC-DC converter (3), the DC-DC converter (4) and the cooling device (12).

According to an aspect of the present invention, a luminaire comprises a light source (20) including at least a solid-state light-emitting device (21); and an electronic ballast (10). The electronic ballast (10) comprises an AC-DC converter (3), a DC-DC converter (4), a cooling device (12) and a power supply (1A). The AC-DC converter (3) comprises a chopper circuit (28) configured to convert an AC voltage ( $V_{AC}$ ) from a commercial power supply (1) into a first DC voltage (V1). The DC-DC converter (4) comprises a DC-DC conversion circuit (41) configured to convert the first DC voltage (V1) into a second DC voltage (V2) to supply the second DC voltage (V2) to the light source (20). The cooling device (12) is configured to cool the light source (20). The power supply (1A) comprises a first power supply (7) and a second power supply (8). The first power supply (7) is configured to generate a first operating voltage (V11) from a first voltage obtained from the chopper circuit (28) to supply the first operating voltage (V11) to at least one of the AC-DC converter (3) and the DC-DC converter (4). The second power supply (8) is configured to generate a second operating voltage (V12) from a second voltage obtained from the chopper circuit (28) to supply the second operating voltage (V12) to at least the cooling device (12) of the AC-DC converter (3), the DC-DC converter (4) and the cooling device (12).

In the present invention, it is possible to supply a stable voltage to a cooling device and further prevent light source's temperature from rising.

### BRIEF DESCRIPTION OF THE DRAWINGS

The figures depict one or more implementations in accordance with the present teaching, by way of example only, not by way of limitations. In the figure, like reference numerals refer to the same or similar elements where:

FIG. 1 exemplifies a schematic circuit diagram of an electronic ballast in accordance with an embodiment of the present invention;

FIGS. 2A to 2D exemplify other configurations of a DC-DC converter in the electronic ballast;

FIG. 3 exemplifies a circuit diagram of a first power supply in the electronic ballast;



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FIG. 4 exemplifies a schematic diagram of luminaire with the electronic ballast;

FIG. 5 exemplifies a schematic circuit diagram of an electronic ballast in accordance with an embodiment of the present invention; and

FIG. 6 exemplifies a schematic circuit diagram of an electronic ballast in accordance with an embodiment of the present invention.

#### DETAILED DESCRIPTION

An electronic ballast (an LED ballast) 10 in accordance with an embodiment of the present invention is now explained with reference to FIGS. 1 to 3. For example, the electronic ballast 10 is configured to operate a light source 20 including one or more solid-state light-emitting devices 21. In the embodiment, the light source 20 includes solid-state light-emitting devices 21.

In an example of FIG. 1, the light source 20 has eight solid-state light-emitting devices 21. In the embodiment, light-emitting diodes (LEDs) are employed as the solid-state light-emitting devices 21, and light emission color thereof is set to white. In the example of FIG. 1, a connection configuration of the solid-state light-emitting devices 21 is a series connection, but the invention is not limited to this. As an embodiment of the invention, the connection configuration may be a parallel connection or a combination of a series connection and a parallel connection.

The electronic ballast 10 includes a filter 2, an AC-DC converter 3, a DC-DC converter 4, a power supply 1A, a cooling device 12 and a main controller 11. The filter 2 is configured to remove noise (e.g., noise from and/or to a commercial power supply 1).

The AC-DC converter 3 includes a chopper circuit 28 that is configured to convert an AC (alternating current) voltage  $V_{AC}$  from the commercial power supply 1 into a first DC (direct current) voltage V1. In the example of FIG. 1, the AC-DC converter 3 includes a full-wave rectifier 18 and a first control circuit 5 in addition to the chopper circuit 28.

The DC-DC converter 4 includes a DC-DC conversion circuit 41 that is configured to convert the first DC voltage V1 into a second DC voltage V2 to supply the second DC voltage V2 to the light source 20. In the example of FIG. 1, the DC-DC converter 4 includes a second control circuit 6 in addition to the DC-DC conversion circuit 41.

In the embodiment, the first DC voltage V1 and the second DC voltage V2 are set to, for example, 410V and 150V, respectively.

The first control circuit 5 is configured to control the chopper circuit 28 of the AC-DC converter 3. The second control circuit 6 is configured to control the DC-DC conversion circuit 41 of the DC-DC converter 4.

The power supply 1A includes a first power supply 7 and a second power supply 8. The first power supply 7 is configured to generate a first operating voltage V11 from a first voltage obtained from the chopper circuit 28 to supply the first operating voltage V11 to at least one of the AC-DC converter 3 and the DC-DC converter 4. The second power supply 8 is configured to generate a second operating voltage V12 from a second voltage obtained from the chopper circuit 28 to supply the second operating voltage V12 to at least the cooling device 12 of the AC-DC converter 3, the DC-DC converter 4 and the cooling device 12.

In the example of FIG. 1, the first power supply 7 is configured to supply the first operating voltage V11 to the AC-DC converter 3 and the DC-DC converter 4. Specifically, the first power supply 7 is configured to generate the first operating

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voltage V11 for the first control circuit 5 and the second control circuit 6 from the first voltage to supply the first operating voltage V11 to the first control circuit 5 and the second control circuit 6, where the first voltage is the first DC voltage V1. In the embodiment, the first operating voltage V11 is set to, for example, 12V. The second power supply 8 is configured to generate the second operating voltage V12 for the cooling device 12 from the second voltage to supply the second operating voltage V12 to the cooling device 12.

In the example of FIG. 1, the power supply 1A further includes a third power supply 9. The third power supply 9 is configured to generate a third operating voltage V13 for the main controller 11 from an output of the first power supply 7 (the first operating voltage V11) to supply the third operating voltage V13 to the main controller 11. In the embodiment, the third operating voltage V13 is set to, for example, a voltage in a range of 3-5V.

The cooling device 12 is configured to cool the light source 20 to be connected to an output side of the DC-DC converter 4. In the example of FIG. 1, the cooling device 12 is formed of a rotor (an impeller) 13, a driver 14 and a temperature sensor 15.

The main controller 11 is configured to individually control the first control circuit 5 and the second control circuit 6.

The electronic ballast 10 also includes a pair of power input terminals 1a and 1b, first and second power output terminals 16a and 16b, and a signal input terminal 17 configured to receive a signal from an outside (a dimming signal). In the example of FIG. 1, the first power output terminal 16a and the second power output terminal 16b are a positive output terminal and a negative output terminal, respectively.

Hereinafter, each component of the electronic ballast 10 is explained in details.

The filter 2 may be formed of, for example, a filter circuit including a common mode filter formed of at least one capacitor (not shown) and first and second inductors (not shown). For example, a first end of the first inductor is connected to a side of the power input terminal 1a, and a first end of the second inductor is connected to a side of the power input terminal 1b. The capacitor is connected between the first ends or second ends of the first and second inductors. In this case, the first ends of the first and second inductors constitute a pair of input ends of the filter 2, and the second ends of the first and second inductors constitute a pair of output ends of the filter 2.

The pair of input ends of the filter 2 is electrically connected to the commercial power supply 1 through the pair of power input terminals 1a and 1b. In the example of FIG. 1, the pair of input ends of the filter 2 is individually connected to the pair of power input terminals 1a and 1b, and the commercial power supply 1 is connected between the pair of power input terminals 1a and 1b. In the embodiment, a switch (not shown) configured to make or break an electrical connection between the commercial power supply 1 and the electronic ballast 10 is provided along a power supply line between the commercial power supply 1 and one of the pair of power input terminals 1a and 1b. In this case, the commercial power supply 1 is not included in a component of the electronic ballast 10.

For example, a diode bridge may be employed as the full-wave rectifier 18 of the AC-DC converter 3. In the example of FIG. 1, diodes 181 to 184 constitute the diode bridge. Specifically, a first end of the diode 181 and a first end of the diode 183 are connected and constitute a positive output end of the full-wave rectifier 18. A second end of the diode 181 and a first end of the diode 182 are connected and constitute an input end of the full-wave rectifier 18. A second end of the



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diode **183** and a first end of the diode **184** are connected and constitute another input end of the full-wave rectifier **18**. A second end of the diode **182** and a second end of the diode **184** are connected and constitute a negative output end of the full-wave rectifier **18**. In this example, each first end of the diodes **181** to **184** is a cathode, and each second end is an anode. In short, the full-wave rectifier **18** has a pair of input ends, and the positive and negative output ends. The pair of input ends of the full-wave rectifier **18** is individually connected to the pair of output ends of the filter **2**.

For example, a boost chopper circuit (a boost converter) may be employed as the chopper circuit **28**. The chopper circuit **28** includes a switching device **Q1** and is configured so that the switching device **Q1** is turned on and off in accordance with control (a control signal) of the first control circuit **5** and thereby an AC voltage from the commercial power supply **1** is increased to the first DC voltage **V1**.

In the example of FIG. **1**, the chopper circuit **28** includes an inductor **L1**, a diode **D1** and a capacitor **C1** in addition to the switching device **Q1**. The inductor **L1** is formed of a choke coil for chopper.

A first end of the inductor **L1** is connected to the positive output end of the full-wave rectifier **18**. A second end of the inductor **L1** is connected to an anode side of the diode **D1**. A cathode of the diode **D1** is connected to a positive side (i.e., a positive electrode side) of the capacitor **C1**. A negative side (i.e., a negative electrode side) of the capacitor **C1** is connected to the negative output end of the full-wave rectifier **18**. Both ends of the capacitor **C1** constitute output ends of the AC-DC converter **3**.

For example, an N-channel MOSFET that is normally off may be employed as the switching device **Q1**. A first end of the switching device **Q1** (a drain terminal in the example of FIG. **1**) is connected to the anode side of the diode **D1**. A second end of the switching device **Q1** (a source terminal in the example) is connected to the negative side of the capacitor **C1**. A control terminal of the switching device **Q1** (a gate terminal in the example) is connected to the first control circuit **5**.

The second power supply **8** includes an inductor **L2** as a secondary winding magnetically coupled to the inductor **L1** as a primary winding in the chopper circuit **28**, and the aforementioned second voltage is obtained from the inductor **L2**.

In the example of FIG. **1**, the second power supply **8** includes a diode **D2**, a capacitor **C2** and a Zener diode **ZD1** in addition to the inductor **L2**. A first end of the inductor **L2** is connected to the negative output end of the full-wave rectifier **18**. A second end of the inductor **L2** is connected to an anode side of the diode **D2**. A cathode of the diode **D2** is connected to a positive side of the capacitor **C2**. A negative side of the capacitor **C2** is connected to the negative output end of the full-wave rectifier **18**. The Zener diode **ZD1** is provided between both ends of the capacitor **C2**. A cathode of the Zener diode **ZD1** is connected to the positive side of the capacitor **C2**. An anode of the Zener diode **ZD1** is connected to the negative side of the capacitor **C2**.

For example, a flyback converter may be employed as the DC-DC converter **4**. The DC-DC conversion circuit **41** of the DC-DC converter **4** includes a switching device **Q2** and is configured so that the switching device **Q2** is turned on and off in accordance with control (a control signal) of the second control circuit **6** and thereby an output (the first DC voltage **V1**) of the AC-DC converter **3** is decreased to the second DC voltage **V2**.

In the example of FIG. **1**, the DC-DC conversion circuit **41** includes a transformer **T1**, a diode **D3** and a capacitor **C3** in addition to the switching device **Q2**. For example, an N-chan-

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nel MOSFET that is normally off may be employed as the switching device **Q2**. The transformer **T1** includes an inductor **L3** as a primary winding and an inductor **L4** as a secondary winding.

A first end of the inductor **L3** in the transformer **T1** is connected to a side of the positive output end of the AC-DC converter **3**, namely the positive side of the capacitor **C1**. A second end of the inductor **L3** is connected to a first end of the switching device **Q2** (a drain terminal in the example of FIG. **1**). A second end of the switching device **Q2** (a source terminal in the example) is connected to a side of the negative output end of the AC-DC converter **3** (the negative side of the capacitor **C1**). A control terminal of the switching device **Q2** (a gate terminal in the example) is connected to the second control circuit **6**.

A first end of the inductor **L4** in the transformer **T1** is connected to an anode side of the diode **D3**. A cathode of the diode **D3** is connected to a positive side of the capacitor **C3**. A negative side of the capacitor **C3** is connected to a second end of the inductor **L4**. Both ends of the capacitor **C3** constitute output ends of the DC-DC converter **4**.

A side of the positive output end of the DC-DC converter **4** (the positive side of the capacitor **C3**) is connected to a first end (an anode) of the light source **20** through the first power output terminal **16a**. A side of the negative output end of the DC-DC converter **4** (the negative side of the capacitor **C3**) is connected to a second end (a cathode) of the light source **20** through the second power output terminal **16b**.

In the electronic ballast **10** of the embodiment, a voltage across the capacitor **C3** as the second DC voltage **V2** (an output voltage of the DC-DC converter **4**) is to be applied across the light source **20** through the first and second power output terminals **16a** and **16b**. Thus, the light source **20** can operate by the output voltage of the DC-DC converter **4**.

In the embodiment, the DC-DC conversion circuit **41** of the DC-DC converter **4** is formed of the flyback converter, but not limited to this. Examples of the DC-DC conversion circuit **41** include a forward converter as shown in FIG. **2A**, a boost chopper circuit (a boost converter) as shown in FIG. **2B**, a boost/buck chopper circuit (a boost/buck converter) as shown in FIG. **2C**, and a buck chopper circuit (a buck converter) as shown in FIG. **2D**.

In the forward converter of FIG. **2A**, a first end of an inductor **L3** is connected to the positive side of the capacitor **C1** in the AC-DC converter **3**. A second end of the inductor **L3** is connected to a drain terminal of a switching device **Q2**. A source terminal of the switching device **Q2** is connected to the negative side of the capacitor **C1**. A gate terminal of the switching device **Q2** is connected to the second control circuit **6**. A first end of an inductor **L4** is connected to an anode side of a diode **D3**. A cathode of the diode **D3** is connected to a positive side of a capacitor **C3**. A negative side of the capacitor **C3** is connected to a second end of the inductor **L4**. The positive and negative sides of the capacitor **C3** are connected to the first and second power output terminals **16a** and **16b**, respectively.

In the boost chopper circuit of FIG. **2B**, a first end of an inductor **L3** is connected to the positive side of the capacitor **C1** in the AC-DC converter **3**. A second end of the inductor **L3** is connected to a drain terminal of a switching device **Q2**. The drain terminal of the switching device **Q2** is connected to an anode side of a diode **D3**. A cathode of the diode **D3** is connected to a positive side of a capacitor **C3**. A negative side of the capacitor **C3** is connected to a source terminal of the switching device **Q2**. A source terminal of the switching device **Q2** is connected to the negative side of the capacitor **C1**. A gate terminal of the switching device **Q2** is connected



to the second control circuit 6. The positive and negative sides of the capacitor C3 are connected to the first and second power output terminals 16a and 16b, respectively.

In the boost/buck chopper circuit of FIG. 2C, a first end of an inductor L3 is connected to the positive side in the AC-DC converter 3. A second end of the inductor L3 is connected to a drain terminal of a switching device Q2. A source terminal of the switching device Q2 is connected to the negative side of the capacitor C1. A gate terminal of the switching device Q2 is connected to the second control circuit 6. A first end of the inductor L3 is connected to a negative side of a capacitor C3. A positive side of the capacitor C3 is connected to a cathode of a diode D3. An anode side of the diode D3 is connected to a second end of the inductor L3. The positive and negative sides of the capacitor C3 are connected to the first and second power output terminals 16a and 16b, respectively.

In the buck chopper circuit of FIG. 2D, a cathode of a diode D3 is connected to the positive side of the capacitor C1 in the AC-DC converter 3. An anode side of a diode D3 is connected to a drain terminal of a switching device Q2. A source terminal of the switching device Q2 is connected to the negative side of the capacitor C1. A gate terminal of the switching device Q2 is connected to the second control circuit 6. The cathode of the diode D3 is connected to a positive side of a capacitor C3. A negative side of the capacitor C3 is connected to a first end of an inductor L3. A second end of the inductor L3 is connected to an anode side of the diode D3. The positive and negative sides of the capacitor C3 are connected to the first and second power output terminals 16a and 16b, respectively.

The first control circuit 5 may be formed of, for example, a control IC (integrated circuit). As a concrete example, the control IC of the first control circuit 5 may be, but not limited to, a control IC such as FA5501A control IC for power factor correction, manufactured by Fuji Electric.

The first control circuit 5 is configured to control ON and OFF (switching) of the switching device Q1 in the chopper circuit 28 of the AC-DC converter 3.

The second control circuit 6 may be formed of, for example, a control IC. As a concrete example, the control IC of the second control circuit 6 may be, but not limited to, a control IC such as FA5546 control IC for PWM (pulse width modulation) control, manufactured by Fuji Electric.

The second control circuit 6 is configured to control ON and OFF (switching) of the switching device Q2 in the DC-DC conversion circuit 41 of the DC-DC converter 4.

The first power supply 7 may be formed of, for example, a power supply IC. As a concrete example, the power supply IC of the first power supply 7 may be, but not limited to, MIP3530MS Intelligent Power Device (hereinafter referred to as "IPD"), manufactured by Panasonic.

As shown in FIG. 3, the first power supply 7 includes an IPD 19, six resistors R1 to R6, seven capacitors C4 to C10, an inductor L5, two diodes D4 and D5, a switching device Q3 and a Zener diode ZD2. In addition, the first power supply 7 includes first and second input terminals 35a and 35b, and first and second output terminals 36a and 36b. In an example of FIG. 3, a PNP bipolar transistor is employed as the switching device Q3.

As shown in FIG. 3, pin #1 of the IPD 19, depicted by "F" is connected to pin #2 of the IPD 19, depicted by "VDD". Pin #1 and pin #2 of the IPD 19 are connected to pin #7 and pin #8 of the IPD 19, depicted by two "S" through a parallel circuit of the capacitors C4 and C5. Pin #3 of the IPD 19, depicted by "CL" is connected to pin #7 and #8 of the IPD 19 through a parallel circuit of the capacitor C6 and the resistor R1. Pin #4 of the IPD 19, depicted by "FB" is connected to pin #7 and #8

of the IPD 19 through a parallel circuit of the capacitor C7 and a series circuit of the resistor R2 and the capacitor C8. The resistor R2 is connected to pin #4 of the IPD 19, and the capacitor C8 is connected to pin #7 and pin #8 of the IPD 19.

An end of the resistor R2 connected to pin #4 of the IPD 19 is connected to a cathode side of the diode D4 through the resistor R3. An anode side of the diode D4 is connected to a first end (a collector terminal in the example of FIG. 3) of the switching device Q3. A second terminal (an emitter terminal in the example) of the switching device Q3 is connected to the first output terminal 36a through the resistor R4. A control terminal (a base terminal in the example) of the switching device Q3 is connected to the emitter terminal of the switching device Q3 through the capacitor C9. A series circuit of the resistor R5 and the Zener diode ZD2 is connected between the first and second output terminals 36a and 36b. An anode side of the Zener diode ZD2 is connected to the second output terminal 36b. A cathode side of the Zener diode ZD2 is connected to the resistor R5. The base terminal of the switching device Q3 is connected to a junction of the resistor R5 and the Zener diode ZD2 through the resistor R6.

The series circuit of the resistor R5 and the Zener diode ZD2 is connected in parallel with the capacitor C10. A positive side of the capacitor C10 is connected to one end of the resistor R5 connected to the first output terminal 36a. A negative side of the capacitor C10 is connected to the anode of the Zener diode ZD2 connected to the second output terminal 36b. The positive side of the capacitor C10 is connected to a cathode of the diode D5 through the inductor L5. The negative side of the capacitor C10 is connected to an anode of the diode D5. The cathode side of the diode D5 is connected to pin #7 and pin #8 of the IPD 19. The anode side of the diode D5 is connected to the second input terminal 35b. The first input terminal 35a is connected to pin #5 of the IPD 19, depicted by "D".

In the embodiment, the first input terminal 35a is connected to the positive side of the capacitor C1 in the AC-DC converter 3, and the second input terminal 35b is connected to the negative side of the capacitor C1. In the example of FIG. 1, the first output end 36a is connected to the first control circuit 5, the second control circuit 6 and the third power supply 9, and the second output terminal 36b is connected to a common ground (not shown) of the first control circuit 5 and the second control circuit 6.

The first power supply 7 is configured to generate the first operating voltage V11 from a voltage across the capacitor C1 (an output voltage of the AC-DC converter 3) as the first DC voltage V1, and to supply the first operating voltage V11 to the first control circuit 5, the second control circuit 6 and the third power supply 9.

The cooling device 12 may be formed of an air cooling device (e.g., an axial flow fan). In the example of FIG. 1, the cooling device 12 includes the rotor (the impeller) 13 and the driver 14. The rotor (the impeller) 13 includes vanes 13a, and a rotation axis 13b to which the vanes 13a are attached, and is configured so that the vanes 13a are free to rotate clockwise or counterclockwise around the rotation axis 13b. The driver 14 is configured to drive the rotor 13. For example, the driver 14 is formed of a DC motor, and connected to the positive side of the capacitor C2 in the second power supply 8. In the embodiment, the driver 14 is formed of the DC motor, but the invention is not limited to this. As an embodiment of the invention, the driver 14 may be formed of a pulse motor or the like. In this case, it is possible to suitably set a rotation speed of the rotor 13 and to adjust cooling capability of the cooling device 12. In the example of FIG. 1, the cooling device 12 is formed of the air cooling device, but is not limited to this. Examples



of the cooling device **12** include a water cooling device configured to circulate water with a pump, a Peltier cooling device with Peltier element, and the like.

The cooling device **12** is configured to operate by receiving electric power from the inductor **L2** as the secondary winding magnetically coupled to the inductor **L1** as the primary winding in the chopper circuit **28**. That is, in the electronic ballast **10**, a first voltage (an induced voltage) induced across the inductor **L2** is to be applied across the capacitor **C2** through the diode **D2**. A voltage across the capacitor **C2** is to be then supplied as the second operating voltage **V12** to the driver **14**. In the example of FIG. 1, the diode **D2** and the capacitor **C2** constitute a rectifier smoothing circuit configured to rectify the first voltage induced across the inductor **L2** and also to remove the ripples therefrom. In the embodiment, the first voltage induced across the inductor **L2** is set to, for example, a voltage in a range of 5 to 12V.

It is therefore possible to supply the driver **14** with the second operating voltage **V12** obtained from the first voltage induced across the inductor **L2** to operate the cooling device **12**. As a result, the electronic ballast **10** can effectively dissipate heat generated in the light source **20**. In the embodiment, the second operating voltage **V12** is set to, for example, a voltage in a range of 5 to 12V.

Since the Zener diode **ZD1** is connected in parallel with the capacitor **C2**, the electronic ballast **10** can prevent the second operating voltage **V12** from exceeding a Zener voltage of the Zener diode **ZD1**. As a result, the electronic ballast **10** prevent malfunction of the cooling device **12**. In the embodiment, the Zener voltage of the Zener diode **ZD1** is set to, for example, 12V.

In the embodiment, the second power supply **8** configured to generate the second operating voltage **V12** for activating only the cooling device **12** is physically separated from the first power supply **7**, and accordingly the electronic ballast **10** can supply a stable voltage to the cooling device **12**. In addition, since the second operating voltage **V12** is supplied from the second power supply **8** to the cooling device **12**, the electronic ballast **10** can further increase the second operating voltage **V12** in comparison with the LED lighting device of Document 1. It is accordingly possible to employ the cooling device **12** having higher cooling capability. As a result, the electronic ballast **10** can further prevent light source's (**20**) temperature from rising in comparison with the LED lighting device of Document 1.

The main controller **11** is formed of, for example, a microcomputer and a suitable program installed in the main controller **11**. The program is stored in a memory unit (not shown) provided in the microcomputer.

The main controller **11** is connected to each of the first control circuit **5** and the second control circuit **6**. That is, the main controller **11** is configured to control ON and OFF of the switching device **Q1** in the chopper circuit **28** through the first control circuit **5** and also to control ON and OFF of the switching device **Q2** in the DC-DC conversion circuit **41** through the second control circuit **6**.

The main controller **11** is also connected with the temperature sensor **15** that is configured to detect (measure) the light source' (**20**) temperature. The temperature sensor **15** may be formed of, for example, a thermistor or the like. For example, the main controller **11** may be configured to activate the cooling device **12** by controlling ON and OFF of the switching device **Q1** in the chopper circuit **28** through the first control circuit **5** if the temperature sensor **15** detects that the light source' (**20**) temperature is a predetermined temperature or more. In this example, heat generated in the light source **20** can be dissipated effectively.

The main controller **11** is further connected to the signal input terminal **17**. In the embodiment, the main controller **11** is configured to receive a dimming signal from the signal input terminal **17**. Examples of the dimming signal include a DALI (Digital Addressable Lighting Interface) signal, a DMX (Digital Multiplex) signal, a PWM (Pulse Width Modulation) signal, a DC (Direct Current) signal, and the like.

The main controller **11** is configured to control the switching device **Q2** in the DC-DC conversion circuit **41** through the second control circuit **6** in accordance with a dimming signal if receiving the dimming signal. Specifically, the main controller **11** is configured to control ON duty ratio of the switching device **Q2** in the DC-DC conversion circuit **41** through the second control circuit **6** in accordance with a dimming signal if receiving the dimming signal. As a result, the electronic ballast **10** can control light output of the light source **20**.

In the embodiment, the main controller **11** is configured, if receiving a dimming signal, to control ON duty ratio of the switching device **Q2** in accordance with the dimming signal, but the invention is not limited to this. As an embodiment of the invention, the main controller **11** may be configured to control OFF duty ratio of the switching device **Q2**.

In the embodiment, the main controller **11** is configured, if receiving a dimming signal, to control the switching device **Q2** through the second control circuit **6** in accordance with the dimming signal, but the invention is not limited to this. As an embodiment of the invention, the main controller **11** may be configured to control the switching device **Q1** through the first control circuit **5** in accordance with a dimming signal. For example, the main controller **11** may be configured, if receiving a dimming signal, to control ON duty ratio or OFF duty ratio of the switching device **Q1** in the chopper circuit **28** through the first control circuit **5** in accordance with the dimming signal. As another example, the main controller **11** may be configured, if receiving a dimming signal, to control the switching devices **Q1** and **Q2** through the first and second control circuits **5** and **6** in accordance with the dimming signal.

The third power supply **9** may be formed of, for example, a three-terminal regulator. For example, the third power supply **9** may be formed of, but not limited to, a device such as S-812C series voltage regulator manufactured by Seiko Instruments.

In the example of FIG. 1, an input terminal and an output terminal of the third power supply **9** are connected to the first power supply **7** and the main controller **11**, respectively. A ground terminal (not shown) of the third power supply **9** is connected to a ground (not shown) of the electronic ballast **10**.

The third power supply **9** is configured to generate the third operating voltage **V13** from the first operating voltage **V11** of the first power supply **7** to supply the third operating voltage **V13** to the main controller **11**.

In the embodiment, each of the first control circuit **5** and the second control circuit **6** includes a control IC, but the invention is not limited to this. As an embodiment of the invention, each of the first control circuit **5** and the second control circuit **6** may include a microcomputer and a suitable program installed in the microcomputer. As another embodiment, both of the first control circuit **5** and the second control circuit **6** may be formed of one microcomputer.

In the embodiment, the light source **20** includes at least a light-emitting diode as at least a solid-state light-emitting device **21**, but the invention is not limited to this. As an embodiment of the invention, the light source **20** may include an organic electroluminescence element(s), a semiconductor laser element(s) or the like.



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As described above, the electronic ballast **10** in the embodiment includes the AC-DC converter **3**, the DC-DC converter **4**, the cooling device **12** and the power supply **1A**. The AC-DC converter **3** includes the chopper circuit **28** and the first control circuit **5**. The chopper circuit **28** is configured to convert an AC voltage  $V_{AC}$  from the commercial power supply **1** into a first DC voltage  $V1$ . The DC-DC converter **4** includes the DC-DC conversion circuit **41** and the second control circuit **6**. The DC-DC conversion circuit **41** is configured to convert the first DC voltage  $V1$  into a second DC voltage  $V2$  to supply the second DC voltage  $V2$  to the light source **20**. The cooling device **12** is configured to cool the light source **20**. The first control circuit **5** is configured to control the chopper circuit **28**. The second control circuit **6** is configured to control the DC-DC conversion circuit **41**. The power supply **1A** includes the first power supply **7** and the second power supply **8**. The first power supply **7** is configured to generate a first operating voltage  $V11$  from a first voltage obtained from the chopper circuit **28** to supply the first operating voltage  $V11$  to the first control circuit **5** and the second control circuit **6**. The first voltage is the first DC voltage  $V1$ . The second power supply **8** is configured to generate a second operating voltage  $V12$  from a second voltage obtained from the chopper circuit **28** to supply the second operating voltage  $V12$  to the cooling device **12**. The second power supply **8** includes the inductor  $L2$  magnetically coupled to the inductor  $L1$  of the chopper circuit **28**, and the second voltage is obtained from the inductor  $L2$ . As a result, the electronic ballast **10** in the embodiment can supply a stable voltage (the second operating voltage  $V12$ ) to the cooling device **12**, and further prevent light source's (**20**) temperature from rising.

An example of a luminaire with the electronic ballast **10** in the embodiment is now explained with reference to FIG. 4.

The luminaire of the embodiment includes the light source **20** and the electronic ballast **10** configured to operate the light source **20**. The light source **20** and the electronic ballast **10** are to be arranged individually, and the luminaire includes a pair of connecting wires **39** and **39** for connecting the light source **20** and a part of the electronic ballast **10**. In FIG. 4, one of the connecting wires **39** and **39** is seen. It is accordingly possible to downsize the light source **20**.

The light source **20** includes a light emitting module **30** with a mounting substrate **29** on which the solid-state light-emitting devices **21** are mounted, and a case **31** to which the light emitting module **30** is detachably attached. In FIG. 4, only five solid-state light-emitting devices **21** of the light emitting module **30** are seen.

The mounting substrate **29** may be formed of, for example, a metal-based printed circuit board or the like. Preferably, a planar shape of the mounting substrate **29** is a circular shape, but may be a polygonal shape or the like. In the embodiment, the mounting substrate **29** is formed of the metal-based printed circuit board, but not limited to this. Examples of the mounting substrate **29** include a ceramic substrate, a glass epoxy substrate, a paper phenol substrate and the like.

The light emitting module **30** is attached to the case **31** through an insulation sheet **22** that has electric insulation and thermal conductivity.

For example, the case **31** is shaped like a tube with a top base (e.g., a cylinder with a top base). For example, metal such as aluminum, stainless steel, iron, or the like may be employed as material of the case **31**.

The light emitting module **30** is disposed on an inner surface of the top base of the case **31** through the insulation sheet **22**. As a result, the luminaire of the embodiment can effectively transmit heat generated in the light emitting module **30** to the case **31**.

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A diffuser panel **23** configured to diffuse light emitted from the solid-state light-emitting devices **21** is disposed at an opening side of the case **31** (at a lower side in FIG. 4). For example, the diffuser panel **23** is shaped like a board (e.g., a disc). For example, optically-transparent material such as acrylic resin, glass, or the like may be employed as material of the diffuser panel **23**.

The luminaire of the embodiment includes a fixture body **24** configured to retain the light source **20**.

The fixture body **24** is formed of a tubular side wall **24a** and a flange **24b** protruded laterally from a lower edge of the side wall **24a**. For example, metal such as aluminum, stainless steel, iron, or the like may be employed as material of the fixture body **24**.

An inside of the side wall **24a** is shaped like a reversed tapered tube such that an aperture area (an inside diameter) of the side wall **24a** becomes gradually wider (larger) from a top end to a bottom end in the side wall **24a**. The light source **20** (the case **31**) is disposed at the top end of the side wall **24a**. In the luminaire of the embodiment, the diffuser panel **23** is disposed at the opening side of the case **31** in the light source **20**, but the invention is not limited to this. As an embodiment of the invention, the diffuser panel **23** may be disposed at a side of the bottom end of the side wall **24a** in the fixture body **24**.

A pair of mounting brackets **25** and **25** is disposed outside the side wall **24a** of the fixture body **24**, and configured to hold part of a ceiling panel **50**, around a hole **50a** cut in the ceiling panel **50**, between the flange **24b** and the pair of mounting brackets **25** and **25**. With the side wall **24a** inserted into the hole **50a** of the ceiling panel **50** such that the flange **24b** is in contact with a lower surface of the ceiling panel **50** around the hole **50a**, the part of the ceiling panel **50** is held between the flange **24b** and the pair of mounting brackets **25** and **25**. As a result, the fixture body **24** is recessed in the ceiling panel **50**.

The luminaire of the embodiment further includes a case **27** that houses components other than the cooling device **12** in the electronic ballast **10**, namely the filter **2**, the AC-DC converter **3**, the DC-DC converter **4**, the power supply **1A**, the main controller **11**, the pair of power input terminal **1a** and **1b**, the first and second power output terminals **16a** and **16b** and the signal input terminal **17**.

The case **27** is shaped like a box (e.g., a rectangular box). Examples of material of the case **27** include metal, resin and the like. In the example of FIG. 4, the case **27** is disposed on an upper surface of the ceiling panel **50**.

The signal input terminal **17** is exposed at a first side wall (a left side wall in the example of FIG. 4) of the case **27**. In the luminaire of the embodiment, the signal input terminal **17** is connected to a dimmer **26** through a connecting cable **38**. The dimmer **26** is configured to output a dimming signal. In the embodiment, a connection means for connecting the electronic ballast **10** and the dimmer **26** is formed of the connecting cable **38**, but may be formed of a communication device using communication media such as infrared or radio wave.

The first and second power output terminals **16a** and **16b** are exposed at a second side wall (a right side wall in the example of FIG. 4) of the case **27**. In the luminaire of the embodiment, the first and second power output terminals **16a** and **16b** are connected to the light source **20** through a pair of connecting wires **39** and **39**. In the example of FIG. 4, one of the first and second power output terminals **16a** and **16b**, namely the first power output terminal **16a** is seen.

The second side wall of the case **27** is also formed with a through hole (not shown) into which a connecting cable **40** electrically connected to the cooling device **12** is inserted.



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In the luminaire of the embodiment, the cooling device **12** of the electronic ballast **10** is fixed to an opposite side of the top base of the case **31** from the opening of the case **31**. In short, the cooling device **12** is fixed to the light source **20**. The cooling device **12** shown in the example of FIG. 4 includes a case **120** housing the rotor (the impeller) **13** and the driver **14** (see FIG. 1), and slits **120a** are formed in a peripheral wall of the case **120**.

Therefore, the luminaire of the embodiment can cool the light source **20** through the cooling device **12** and effectively dissipate heat transmitted from the solid-state light-emitting devices **21** to the case **31**.

In the luminaire of the embodiment, the light source **20** and the electronic ballast **10** are arranged individually (lighting system with separate ballast), but the invention is not limited to this. As an embodiment of the invention, the light source **20** and the electronic ballast **10** may be housed in the fixture body **24** so as to constitute a single luminaire (luminaire with built-in ballast).

As described above, the luminaire of the embodiment includes the light source **20** and the electronic ballast **10** configured to operate the light source **20**. Therefore, the luminaire of the embodiment can supply a stable voltage (the second operating voltage **V12**) to the cooling device **12**, and further prevent light source's (**20**) temperature from rising.

An electronic ballast **10** in accordance with an embodiment of the present invention is explained with reference to FIG. 5. The electronic ballast **10** of the embodiment differs from the embodiment as shown in FIGS. 1 to 3 in that a first power supply **7** is configured to supply a first operating voltage **V11** to one of a first control circuit **5** and a second control circuit **6**, while a second power supply **8** is configured to supply a second operating voltage **V12** to a cooling device **12** and an other of the first control circuit **5** and the second control circuit **6**. In an example of FIG. 5, the first power supply **7** is configured to supply the first operating voltage **V11** to the second control circuit **6**, while the second power supply **8** is configured to supply the second operating voltage **V12** to the cooling device **12** and the first control circuit **5**. Like kind elements are assigned the same reference numerals as depicted in the embodiment as shown in FIGS. 1 to 3 and not described in detail herein.

In the example of FIG. 5, the first control circuit **5** is electrically connected to a positive side of a capacitor **C2** in the second power supply **8**.

In the electronic ballast **10** of the embodiment, a voltage across the capacitor **C2** is supplied as the second operating voltage **V12** to the first control circuit **5**. In this embodiment, it is unnecessary that the first power supply **7** supply the first operating voltage **V11** to the first control circuit **5**, and the first power supply **7** can be accordingly simplified in comparison with the first power supply **7** shown in FIGS. 1 to 3.

In the example of FIG. 5, a voltage across the capacitor **C2** in the second power supply **8** is supplied to the first control circuit **5**, but may be supplied to the second control circuit **6**. That is, as an alternative example, the second power supply **8** (an inductor **L2**) is configured to supply the second operating voltage **V12** to the second control circuit **6** in place of the first power supply **7**, while the first power supply **7** is configured to supply the first operating voltage **V11** to the first control circuit **5**.

As described above, in the electronic ballast **10** shown in FIG. 5, the first power supply **7** is configured to supply the first operating voltage **V11** to the second control circuit **6**, while the second power supply **8** is configured to supply the second operating voltage **V12** to the cooling device **12** and the first control circuit **5**. As a result, in the electronic ballast **10**, the

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first power supply **7** can be simplified in comparison with the first power supply **7** in the embodiment as shown in FIGS. 1 to 3.

The electronic ballast **10** of the embodiment may be applied to the luminaire shown in FIG. 4.

An electronic ballast **10** in accordance with an embodiment of the present invention is explained with reference to FIG. 6. The electronic ballast **10** of the embodiment differs from the embodiment as shown in FIGS. 1 to 3 in that a first power supply **7** is configured to generate a first operating voltage **V11** from a first DC voltage **V1** to supply the first operating voltage **V11** to a first control circuit **5** and a second control circuit **6**, while a second power supply **8** is configured to generate a second operating voltage **V12** from the first DC voltage **V1** to supply the second operating voltage **V12** to a cooling device **12**. Like kind elements are assigned the same reference numerals as depicted in the embodiment as shown in FIGS. 1 to 3 and not described in detail herein.

In an example of FIG. 6, the second power supply **8** is configured to generate the second operating voltage **V12** for the cooling device **12**. In the embodiment, the first operating voltage **V11** is set to, for example, 12V and the second operating voltage **V12** is set to, for example, a voltage in a range of 5 to 12V.

In the example of FIG. 6, the electronic ballast **10** includes a main controller **11** configured to individually control the first control circuit **5**, the second control circuit **6** and the second power supply **8**.

The second power supply **8** may be formed of, for example, a control IC or the like. In the embodiment, the second power supply **8** is formed of, but not limited to, MIP3530MS IPD for switching power supply, manufactured by Panasonic, like the first power supply **7** shown in FIG. 3. In the example of FIG. 6, a first output terminal **35a** (see FIG. 3) of the second power supply **8** is connected to a positive side of a capacitor **C1** in an AC-DC converter **3**, and a second input terminal **35b** (see FIG. 3) of the second power supply **8** is connected to a negative side of the capacitor **C1**. In addition, a first output terminal **36a** (see FIG. 3) of the second power supply **8** is connected to a driver **14**, and a second output terminal **36b** (see FIG. 3) of the second power supply **8** is connected to ground (not shown) of the electronic ballast **10**.

That is, the second power supply **8** is configured to generate the second operating voltage **V12** from a voltage across the capacitor **C1** in the AC-DC converter **3** (an output voltage of the AC-DC converter **3**) to supply the second operating voltage **V12** to the driver **14**.

Thus, in the electronic ballast **10** of the embodiment, the second power supply **8** configured to generate the second operating voltage **V12** for driving only the cooling device **12** is provided separately from the first power supply **7**, and it is accordingly possible to supply a stable voltage to the cooling device **12**. The second operating voltage **V12** is supplied from the second power supply **8** to the cooling device **12**, and therefore the electronic ballast **10** can further increase the second operating voltage **V12** for driving the cooling device **12** in comparison with the LED lighting device of Document 1 and employ the cooling device **12** having higher cooling capability. As a result, the electronic ballast **10** can further prevent light source's (**20**) temperature from rising in comparison with the LED lighting device of Document 1.

In the example of FIG. 6, the main controller **11** is connected to the second power supply **8**. Accordingly, the main controller **11** can supply the second operating voltage **V12** to the driver **14** through the second power supply **8**, and activate the cooling device **12**.



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As described above, the electronic ballast 10 of the embodiment includes the first power supply 7 configured to generate the first operating voltage V11 for activating the first and second control circuits 5 and 6, and the second power supply 8 configured to generate the second operating voltage V12 for activating the cooling device 12. In this electronic ballast 10, the first power supply 7 is to generate the first operating voltage V11 from the first DC voltage V1 as the output voltage of the AC-DC converter 3, and the second power supply 8 is to generate the second operating voltage V12 from the first DC voltage V1. As a result, the electronic ballast 10 of the embodiment can supply a stable voltage (the second operating voltage V12) to the cooling device 12 and further prevent light source's (20) temperature from rising.

While the foregoing has described what are considered to be the best mode and/or other examples, it is understood that various modifications may be made therein and that the subject matter disclosed herein may be implemented in various forms and examples, and that they may be applied in numerous applications, only some of which have been described herein. It is intended by the following claims to claim any and all modifications and variations that fall within the true scope of the present teachings.

The invention claimed is:

**1.** An electronic ballast, comprising:

an AC-DC converter comprising a chopper circuit configured to convert an AC voltage from a commercial power supply into a first DC voltage;

a DC-DC converter comprising a DC-DC conversion circuit configured to convert the first DC voltage into a second DC voltage to supply the second DC voltage to a light source including at least a solid-state light-emitting device;

a cooling device configured to cool the light source; and

a power supply comprising a first power supply configured to generate a first operating voltage from a first voltage obtained from the chopper circuit to supply the first operating voltage to at least one of the AC-DC converter and the DC-DC converter, and a second power supply configured to generate a second operating voltage from a second voltage obtained from the chopper circuit to supply the second operating voltage to at least the cooling device of the AC-DC converter, the DC-DC converter and the cooling device, wherein:

the chopper circuit comprises an inductor;

the AC-DC converter further comprises a first control circuit configured to control the chopper circuit;

the DC-DC converter further comprises a second control circuit configured to control the DC-DC conversion circuit;

the first power supply is configured to supply the first operating voltage to the first control circuit and the second control circuit, and the first voltage is the first DC voltage; and

the second power supply comprises an inductor magnetically coupled to the inductor of the chopper circuit and is configured to supply the second operating voltage to the cooling device, and the second voltage is obtained from the inductor of the second power supply.

**2.** An electronic ballast, comprising:

an AC-DC converter comprising a chopper circuit configured to convert an AC voltage from a commercial power supply into a first DC voltage;

a DC-DC converter comprising a DC-DC conversion circuit configured to convert the first DC voltage into a

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second DC voltage to supply the second DC voltage to a light source including at least a solid-state light-emitting device;

a cooling device configured to cool the light source; and

a power supply comprising a first power supply configured to generate a first operating voltage from a first voltage obtained from the chopper circuit to supply the first operating voltage to at least one of the AC-DC converter and the DC-DC converter, and a second power supply configured to generate a second operating voltage from a second voltage obtained from the chopper circuit to supply the second operating voltage to at least the cooling device of the AC-DC converter, the DC-DC converter and the cooling device, wherein:

the chopper circuit comprises an inductor;

the AC-DC converter further comprises a first control circuit configured to control the chopper circuit;

the DC-DC converter further comprises a second control circuit configured to control the DC-DC conversion circuit;

the first power supply is configured to supply the first operating voltage to one of the first control circuit and the second control circuit, while the second power supply is configured to supply the second operating voltage to the cooling device and an other of the first control circuit and the second control circuit; and

the second power supply comprises an inductor magnetically coupled to the inductor of the chopper circuit, and the second voltage is obtained from the inductor of the second power supply.

**3.** An electronic ballast, comprising:

an AC-DC converter comprising a chopper circuit configured to convert an AC voltage from a commercial power supply into a first DC voltage;

a DC-DC converter comprising a DC-DC conversion circuit configured to convert the first DC voltage into a second DC voltage to supply the second DC voltage to a light source including at least a solid-state light-emitting device;

a cooling device configured to cool the light source; and

a power supply comprising a first power supply configured to generate a first operating voltage from a first voltage obtained from the chopper circuit to supply the first operating voltage to at least one of the AC-DC converter and the DC-DC converter, and a second power supply configured to generate a second operating voltage from a second voltage obtained from the chopper circuit to supply the second operating voltage to at least the cooling device of the AC-DC converter, the DC-DC converter and the cooling device, wherein:

the AC-DC converter further comprises a first control circuit configured to control the chopper circuit;

the DC-DC converter further comprises a second control circuit configured to control the DC-DC conversion circuit;

the first power supply is configured to supply the first operating voltage to the first control circuit and the second control circuit, and the first voltage is the first DC voltage; and

the second power supply is configured to supply the second operating voltage to the cooling device, and the second voltage is the first DC voltage.

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4. A luminaire, comprising:  
 a light source including at least a solid-state light-emitting device; and  
 an electronic ballast, comprising:  
 an AC-DC converter comprising a chopper circuit con- 5  
 figured to convert an AC voltage from a commercial  
 power supply into a first DC voltage;  
 a DC-DC converter comprising a DC-DC conversion  
 circuit configured to convert the first DC voltage into 10  
 a second DC voltage to supply the second DC voltage  
 to the light source;  
 a cooling device configured to cool the light source; and  
 a power supply comprising a first power supply config-  
 ured to generate a first operating voltage from a first 15  
 voltage obtained from the chopper circuit to supply  
 the first operating voltage to at least one of the AC-DC  
 converter and the DC-DC converter, and a second  
 power supply configured to generate a second oper-

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ating voltage from a second voltage obtained from the  
 chopper circuit to supply the second operating voltage  
 to at least the cooling device of the AC-DC converter,  
 the DC-DC converter and the cooling device,  
 wherein:  
 the AC-DC converter further comprises a first control cir-  
 cuit configured to control the chopper circuit;  
 the DC-DC converter further comprises a second control  
 circuit configured to control the DC-DC conversion cir-  
 cuit;  
 the first power supply is configured to supply the first  
 operating voltage to the first control circuit and the sec-  
 ond control circuit, and the first voltage is the first DC  
 voltage; and  
 the second power supply is configured to supply the second  
 operating voltage to the cooling device, and the second  
 voltage is the first DC voltage.

\* \* \* \* \*